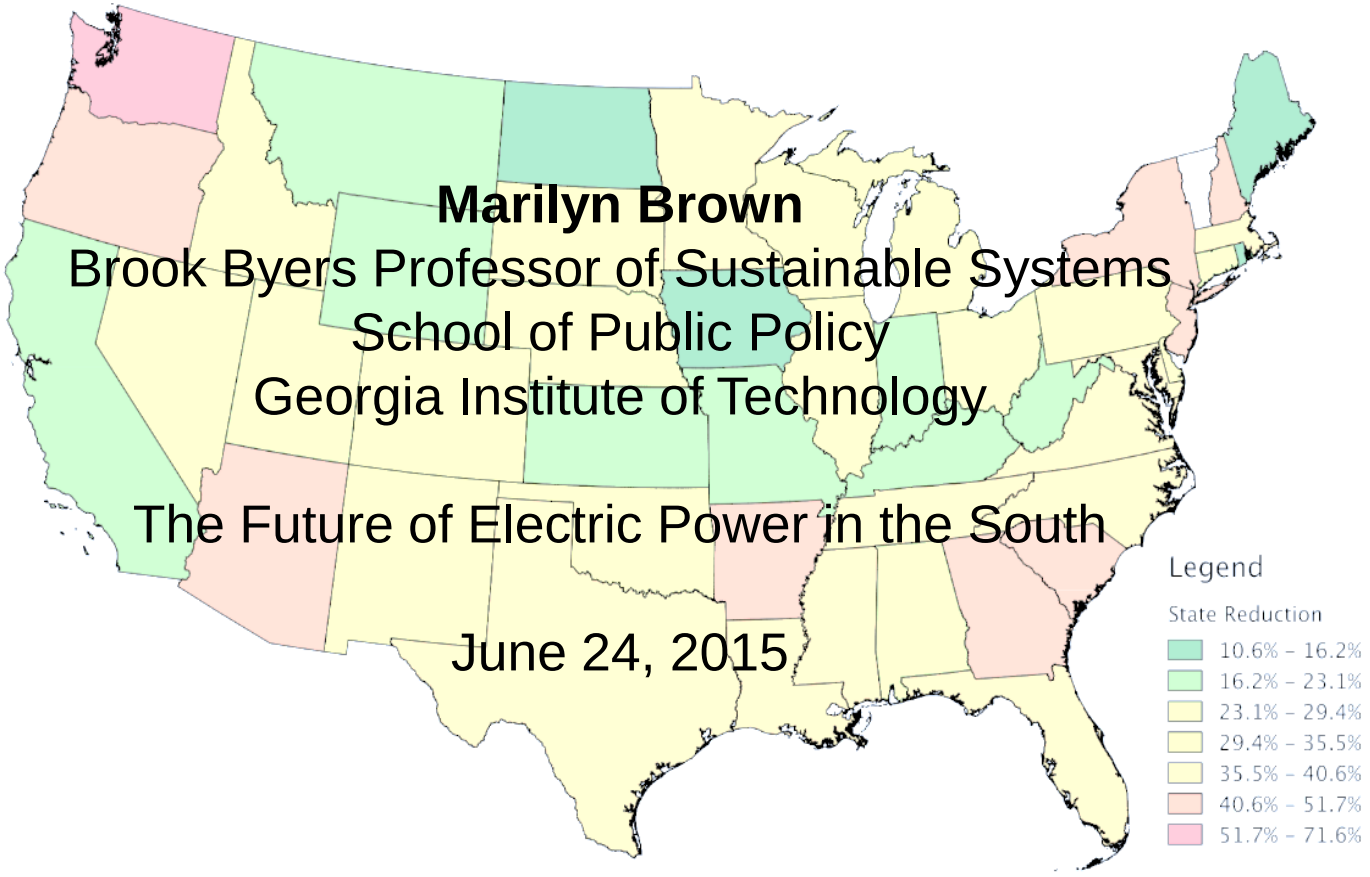
# Low-Carbon Electricity Pathways for the U.S. and the South

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The Future of Electric Power in the South

June 24, 2015

# Motivation and Methodology

# Research Questions



- What is the nation's least-cost pathway for complying with the Clean Power Plan (CPP)?
- Is the least-cost compliance pathway different in the South?
- How will CPP impacts differ across regions of the South?
- Would a regional approach to compliance have merit?
- What do our results suggest for choosing between mass- versus rate-based goals?

# Research Methodology



- Create region-level goals from EPA state-level goals
  - Use location of fossil-fueled plants to apportion goal shares from states to NERC regions
- Introduce various levels of carbon prices
  - Reflects direct pricing for states that choose that route or an indirect penalty on continued use of high carbon fuels, or the assumed allowance price for a metric ton of $CO_2$ emissions reductions for states that use trading schemes.
- Introduce assumptions of accelerated EE deployment and reduced-cost renewable generation
- Run these scenarios in GT-NEMS
  - Compare the results to EIA's 2014 Reference case

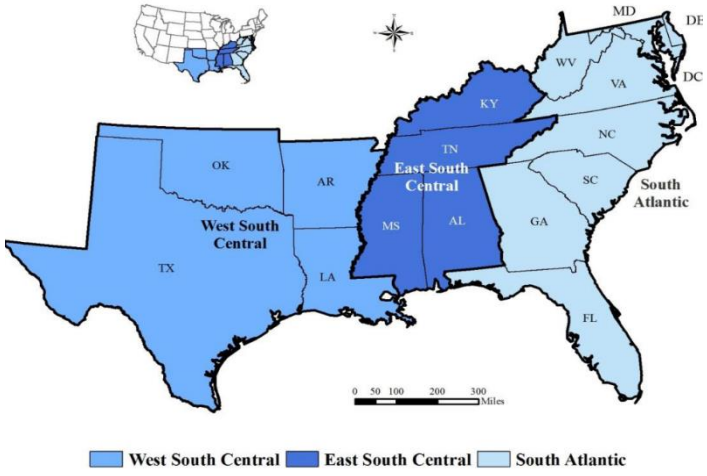
# A Range of Impacts are Examined



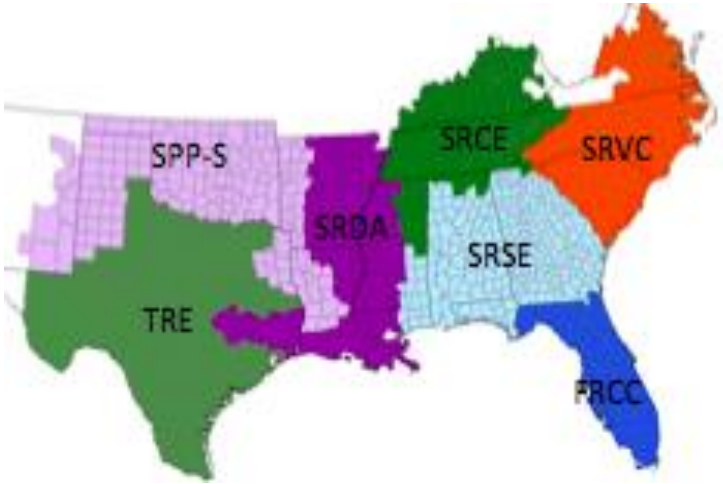
- $CO_2$ emissions
- Fuel mix
- End-use efficiency gains and electricity saved
- Electricity rates and bills
- Economic activity
- Other emissions from the electric power sector

# Defining the "South" in GT-NEMS






**Census Divisions in the South**




**NERC Regions in the South**

# The Seven Southern Regions in GT-NEMS



| Abbreviation | NERC Sub Region Name | Geographic Name |
|---|---|---|
| 1. TRE | Texas Regional Entity | Texas |
| 2. FRCC | Florida Reliability Coordinating Council | Florida |
| 12. SRDA | SERC Reliability Corporation - Delta | Mississippi Delta |
| 14. SRSE | SERC - Southeast | Georgia & Alabama |
| 15. SRCE | SERC - Central | Tennessee Valley |
| 16. SRVC | SERC – Virginia & Carolinas | Virginia & Carolinas |
| 18. SPPS | Southwest Power Pool South | Southern Plains |

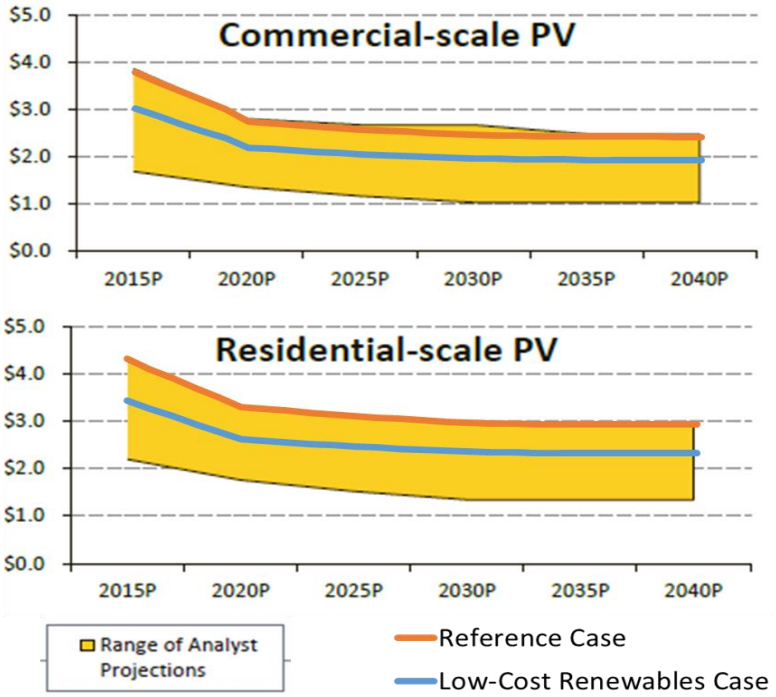
# (1) Modeling of Carbon Prices

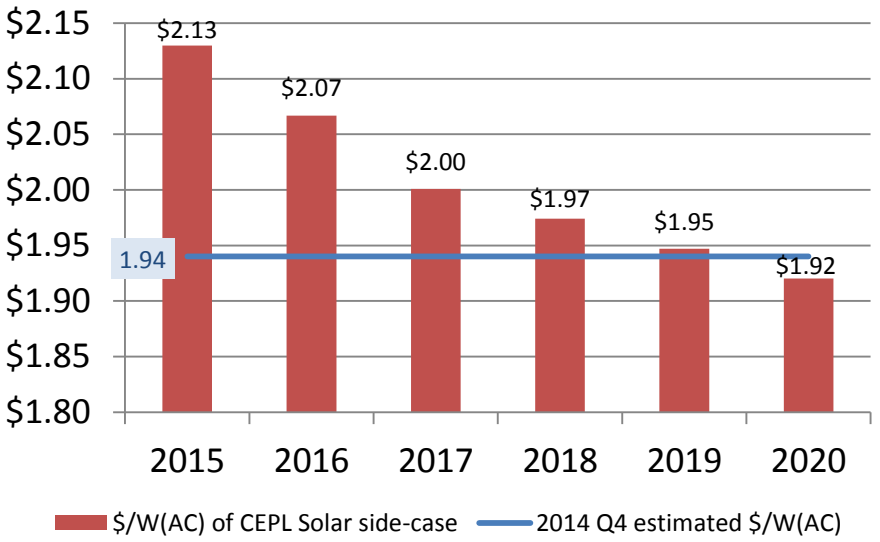


- We modify GT-NEMS to model various levels of carbon pricing starting in 2020 and applied only to the electric power sector.
  - Three levels of prices are studied: $10, $20, and $30/metric tons of $CO_2$
  - In 2012 dollars
  - Applied in 2020 and operation through 2040
- The price level needed to achieve a mass-based goal is one way to estimate compliance cost.
- NEMS operates with foresight, so changes in response to the carbon price begin earlier than 2020.

# (2) Updating Solar Costs



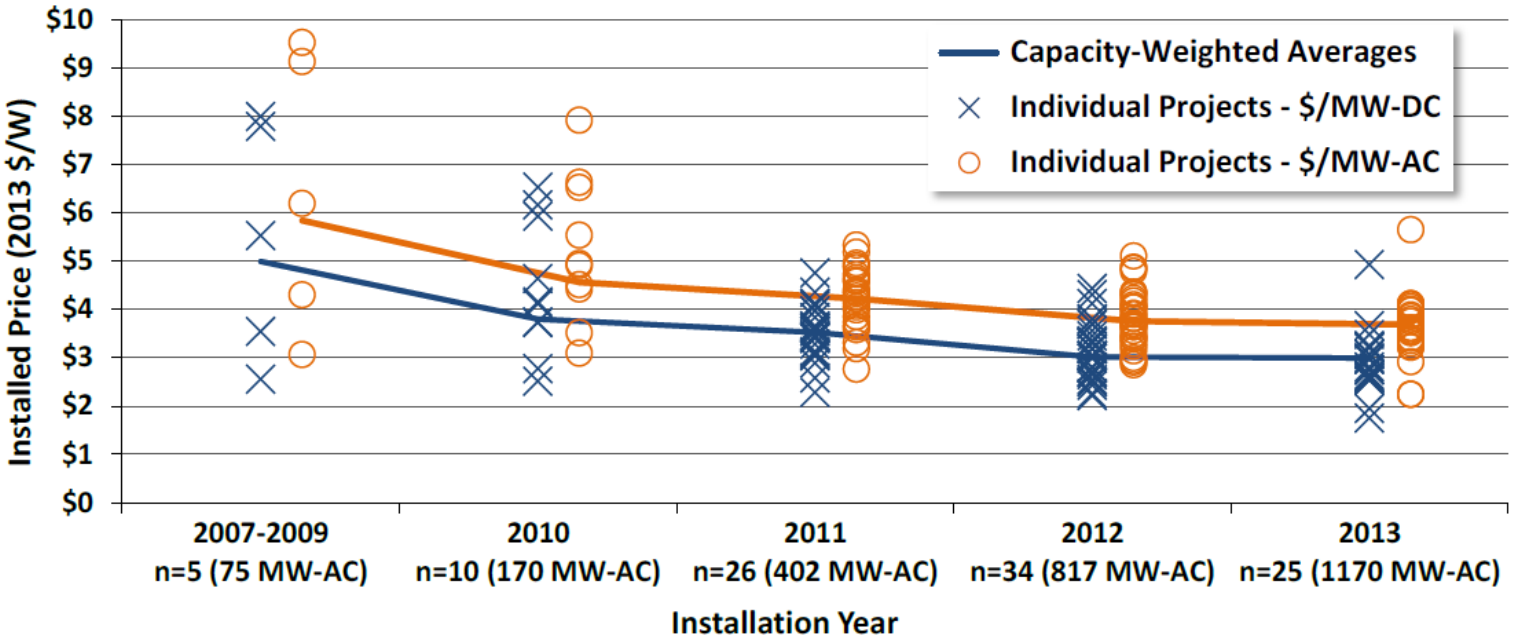



- Used "Tracking the Sun 7" report to update PV costs; by 2030:
  - $1.75/W for utility-scale PV
  - $2/W for commercial-scale PV
  - $2.50/W for residential-scale PV (2010 dollars)
- Also used the low-cost renewables side-case assumptions from EIA

# From $/$W_{DC}$ to $/$W_{AC}$, PV Prices Increase



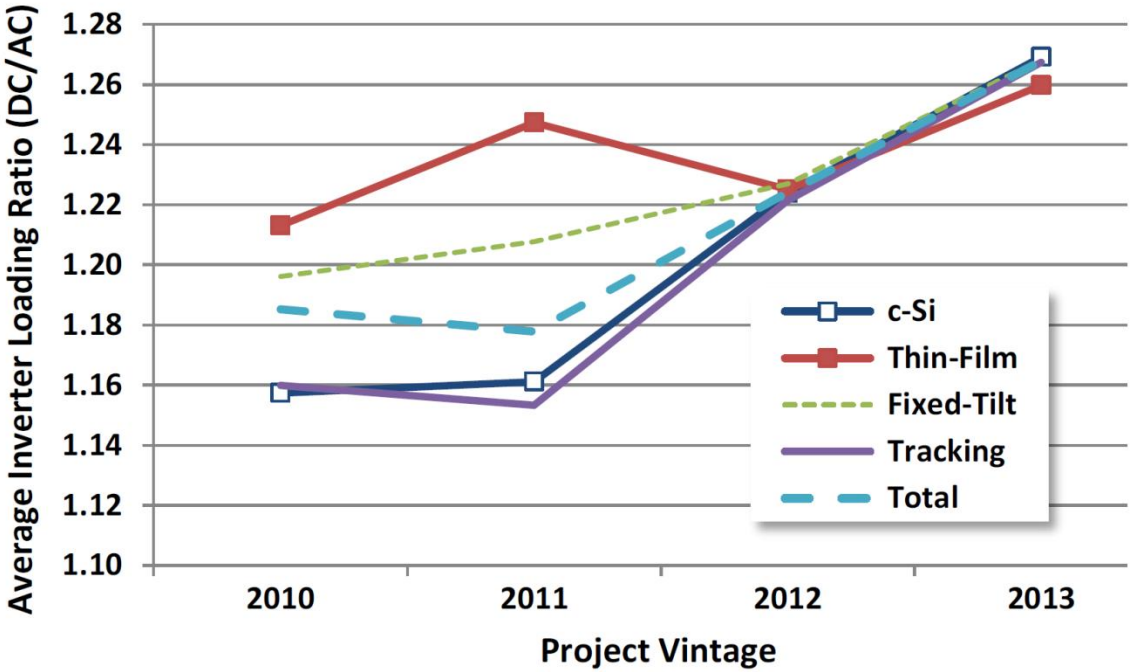



Source: Bolinger and Weaver (2014) *Utility-scale solar 2013: An empirical analysis of project cost, performance, and pricing trends in the United States*. Lawrence Berkeley National Laboratory

- Project developers oversize $W_{DC}$ versus inverter $W_{AC}$
- Average cost ratio is 1.25

# $W_{DC}/W_{AC}$ Ratio Increasing






Source: Bolinger and Weaver (2014) *Utility-scale solar 2013: An empirical analysis of project cost, performance, and pricing trends in the United States*. Lawrence Berkeley National Laboratory

- Greater $W_{DC}/W_{AC}$ ratios ("Inverter Loading Ratios")
  - Boosts capacity factor and hedges risk
  - Incentivized by PPAs favoring longer hours of delivery

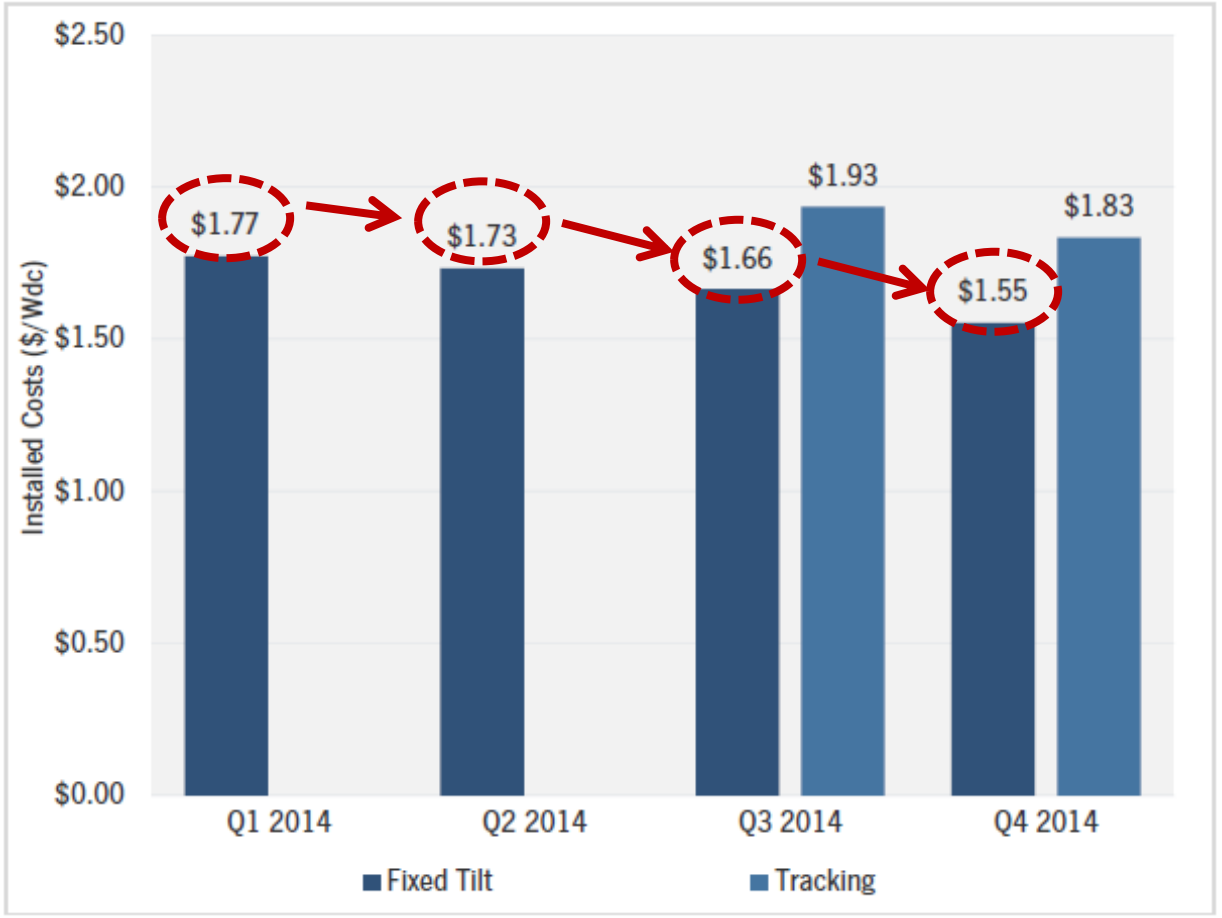
# Utility-scale PV Prices at New Lows



- Q4 2014 cost: $1.55/$W_{DC}$
- To calculate $/$W_{AC}$ ,

$$\$/W_{AC} = (1.25 * \$/W_{DC})$$

$$= \$1.94/ W_{AC}$$




GTM Research and SEIA (2014) *US solar market insight report: 2014 Year in review | Executive summary*.

# (3) Modeling an "Ambitious" Integrated High-Efficiency Case



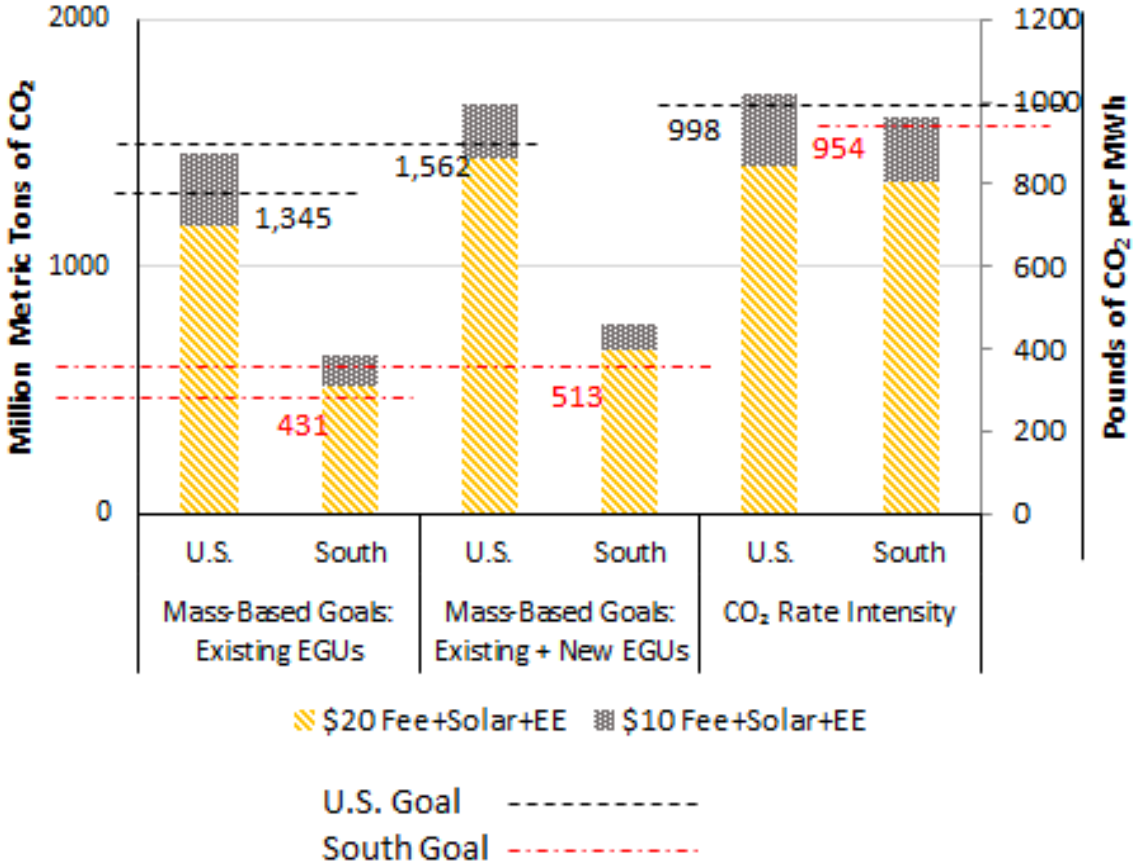
- We employ the assumptions of EIA's High Demand Technology Side Case
  - ✓ Advanced equipment is available earlier, at lower costs, and/or at higher efficiencies
  - ✓ Stricter building codes and greater compliance with those codes
- Stronger appliance and equipment standards
- Lower costs and extended tax credits for industrial CHP
- Increased energy efficiency in five manufacturing sectors
- Changes are introduced throughout the planning period

Note: For more information: http://cepl.gatech.edu/drupal/node/88

# Results

# The U.S. and South can Nearly Meet their Rate-Based Goals with the $10Fee+EE+Solar Pathway

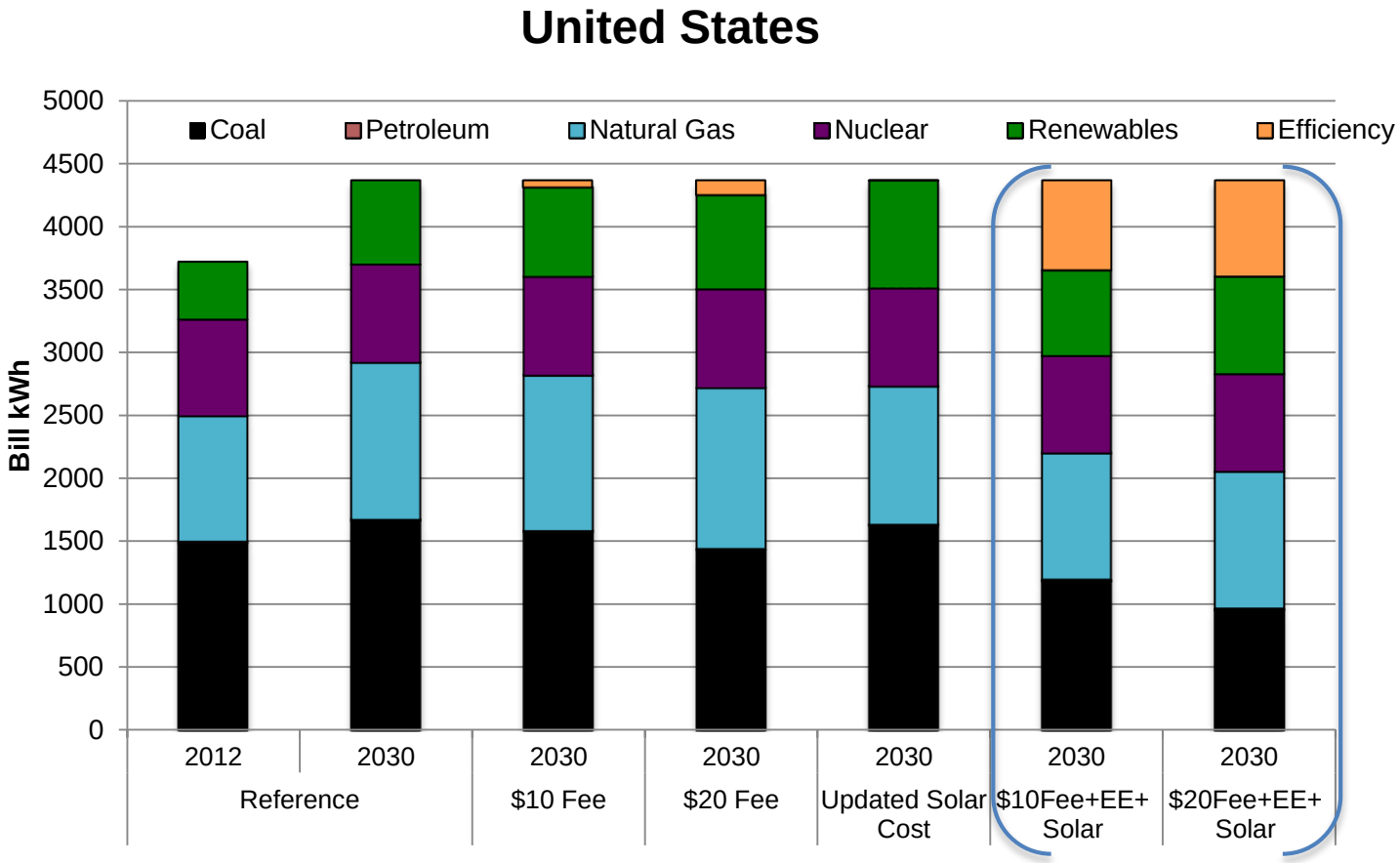





The $10Fee+EE+Solar and $20Fee+EE+Solar scenarios are called “compliance pathways”

# The Compliance Pathways Cut Coal Use, Curb Natural Gas Growth and Increase EE and RE






- The reference case includes naturally occurring energy efficiency
- EE investment costs are included in NEMS

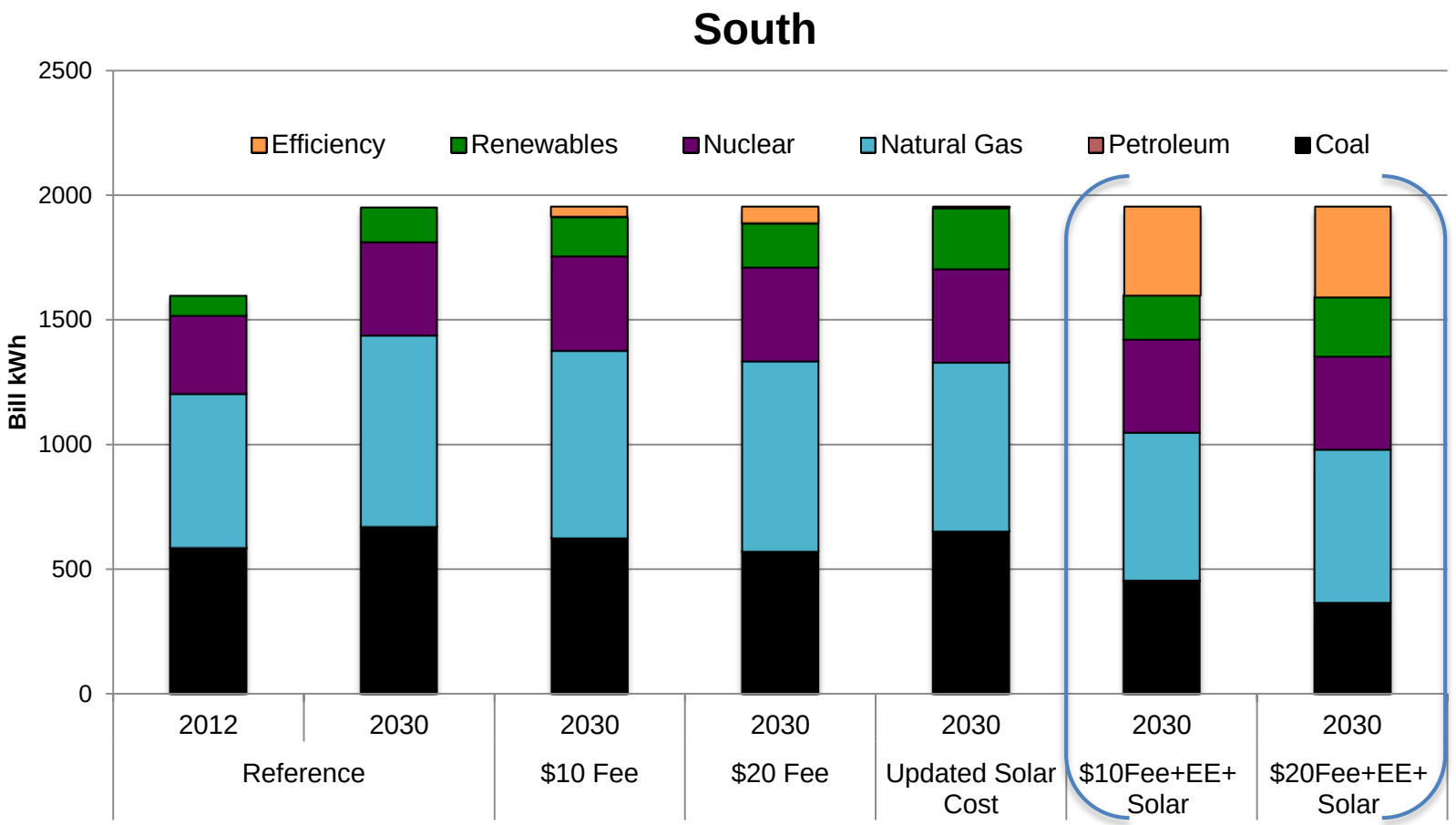
# The Fuel Mix Transformation in the U.S.



- The low-carbon pathways cause little uptake of additional nuclear power
- The low-carbon pathways would cause more wind, biomass, and solar PV (but not geothermal or hydro)
- There appears to be a tipping point for solar PV between the $10 and $20 price per tonne-$CO_2$
- The growth in solar PV mostly displaces wind and natural gas
- The growth of solar is subdued by EE; solar PV grows along with EE when a carbon price is added.
- Without the introduction of additional low-carbon policies such as those proposed by the CPP, coal generation does not decrease between 2012 and 2030

# Similar Fuel Shifting Would Occur in the South





# The South's Distinct Fuel Mix Response



- Coal tends to decline more rapidly in the South
- Natural gas increases less in the South
- Nuclear power increases in the South
- The South shows proportionately more growth in renewable energy and slightly more growth in energy efficiency
- Biomass plays a greater role in the South's renewable portfolio, rivaling the role of wind

# There are Diverse Responses Across the South



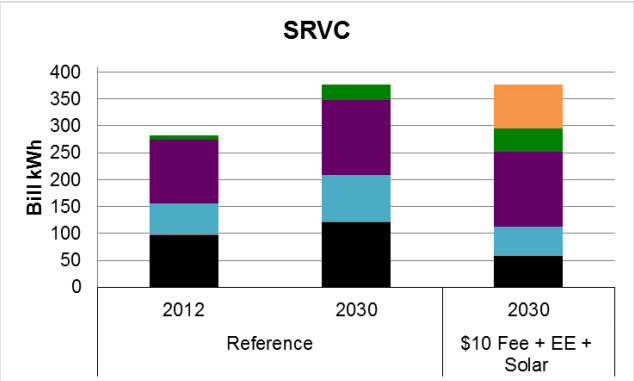
- The three NERC regions with nuclear units under construction require higher carbon prices to achieve compliance.
- The tipping point between the $10Fee+EE+Solar and $20Fee+EE+Solar pathways is shown clearly in several NERC regions
- In three of the seven southern NERC regions, coal power would decline significantly. EE and renewables grow to fill the gap in SRVC and SPPS, and natural gas also grows in SRCE.

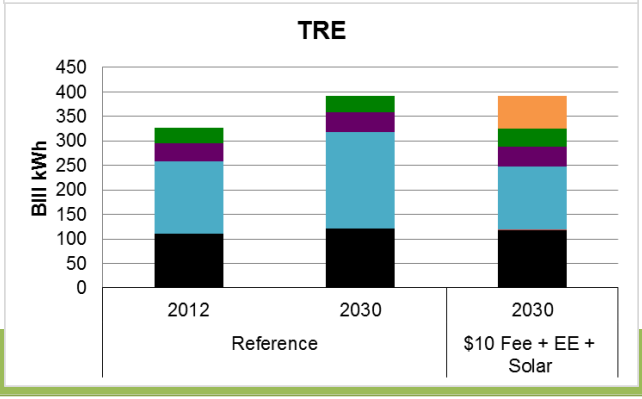
# South's Fuel Mix

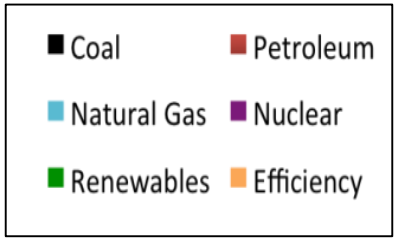


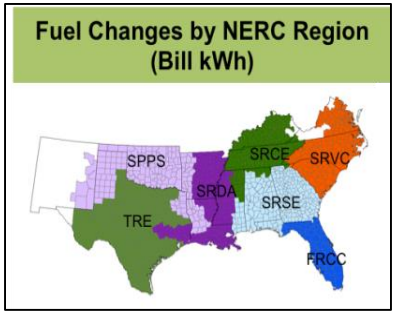
- In southern regions where coal use declines, EE, RE, and natural gas increase to fill the gap, in that order
- Natural gas, EE & renewables: competitive or complementary?

Competitive

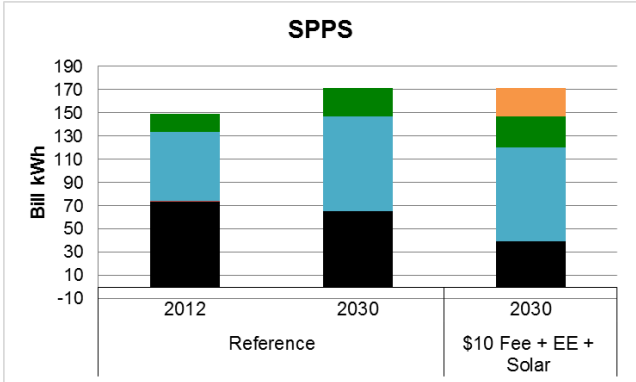


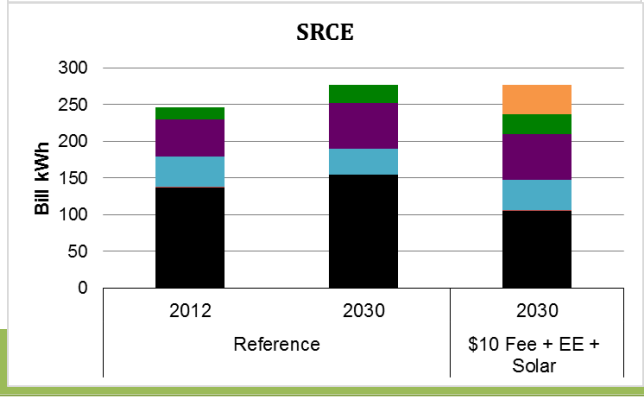



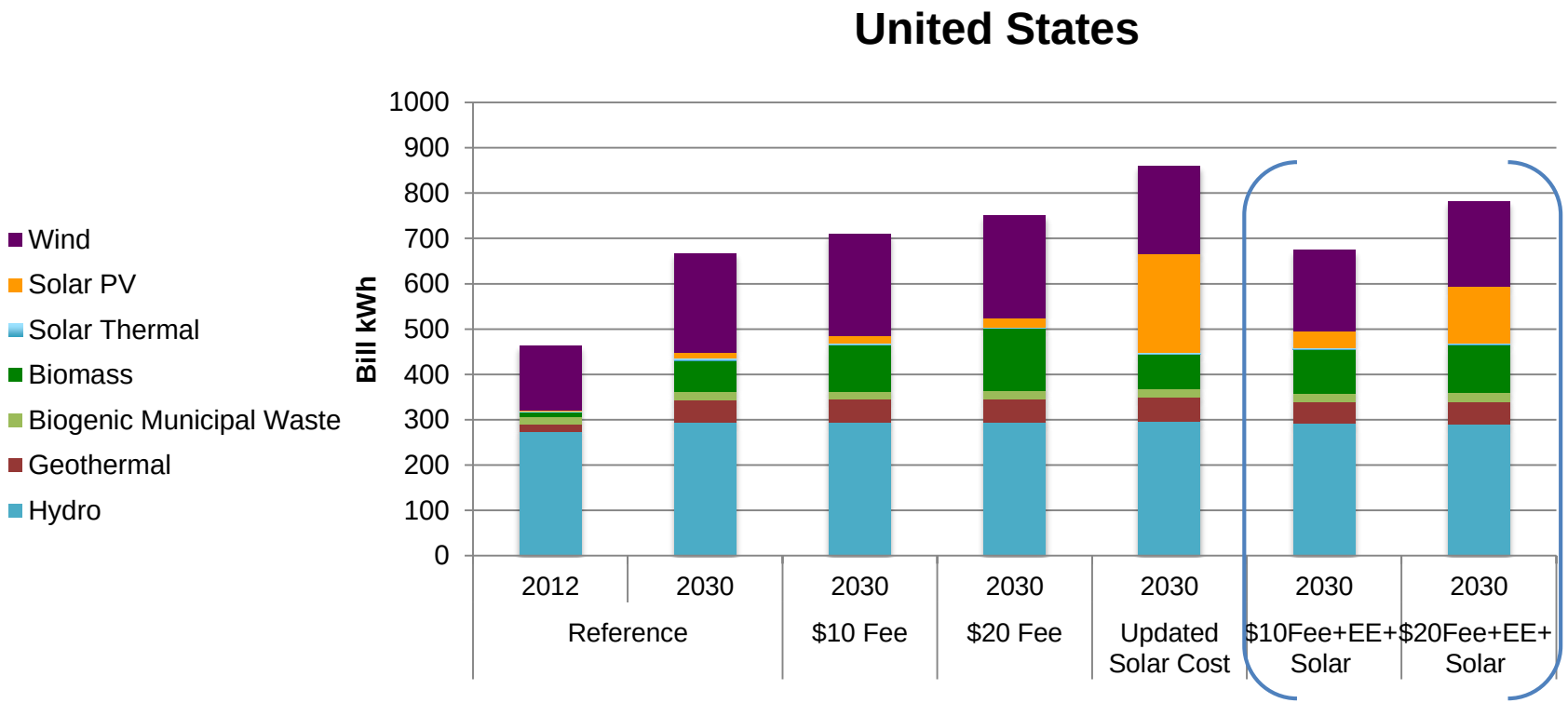

Complementary



# Compliance Pathways Increase Wind, Biomass & Solar; Hydro is Still Dominant

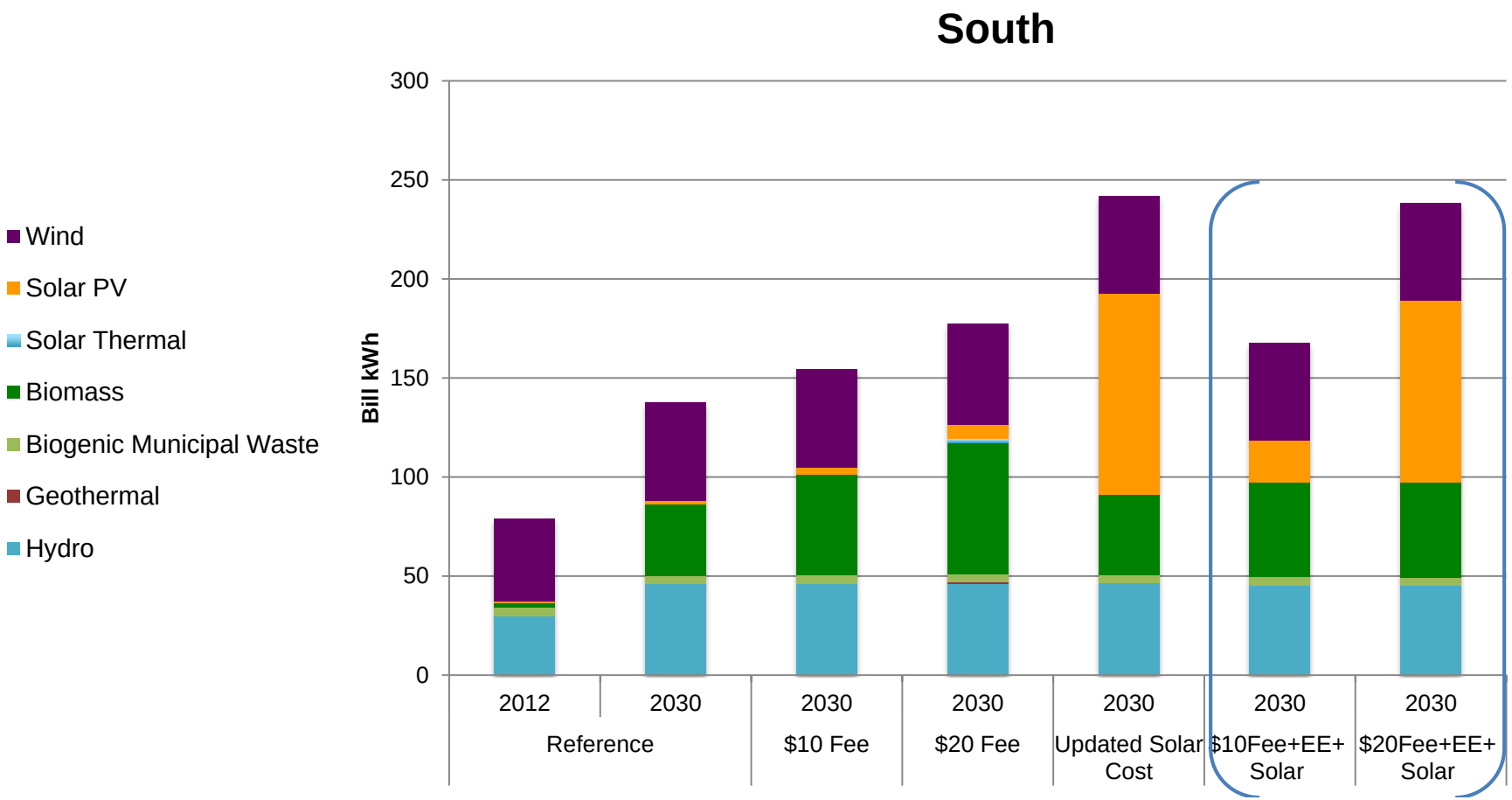





**Limited growth of geothermal and hydro**

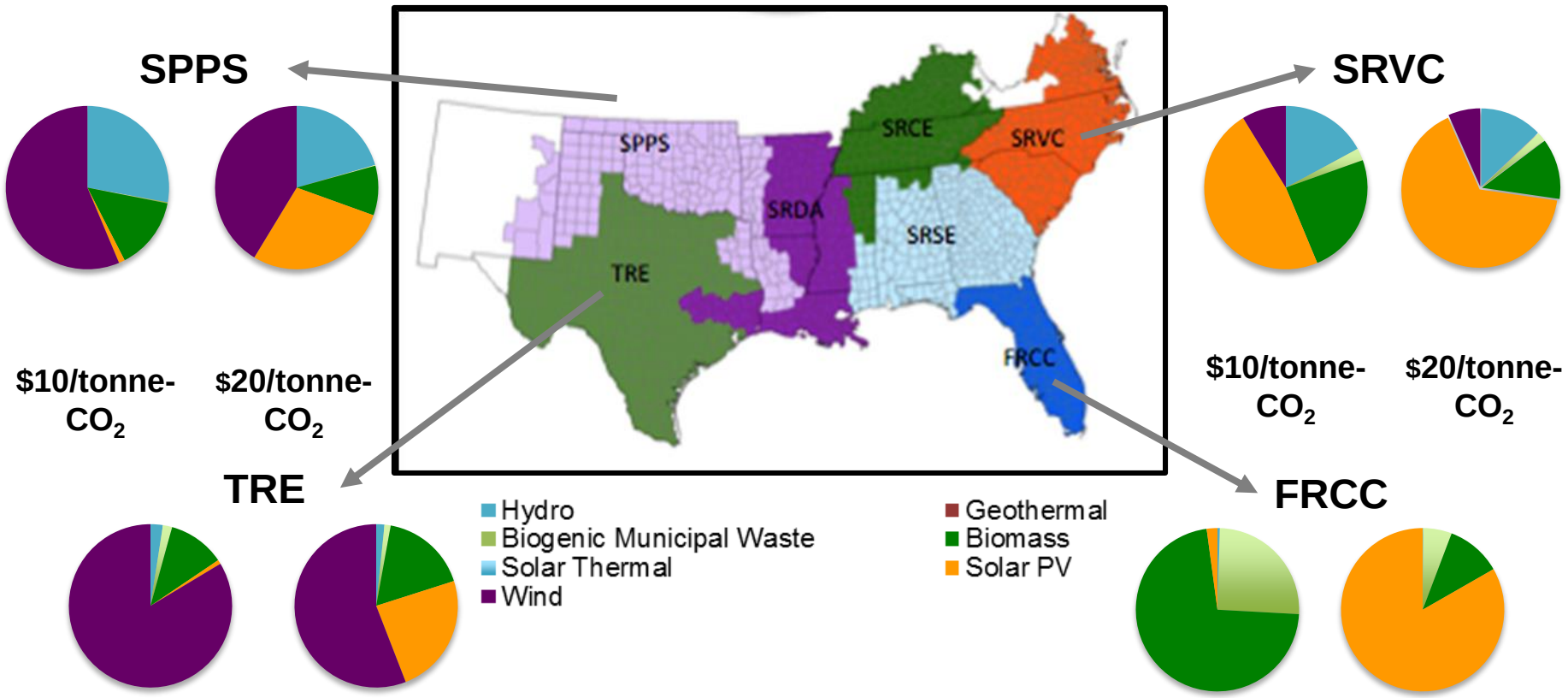
# In the South, Solar Rivals Wind, Biomass, and Hydro in Two Pathways





# Several Regions Reach a "Tipping Point" for Solar PV with $20Fee+EE+Solar






When **$10**/tonne-$CO_2$ increases to **$20**/tonne-$CO_2$ (with EE and solar), significant gains in solar PV generation occur by 2030.

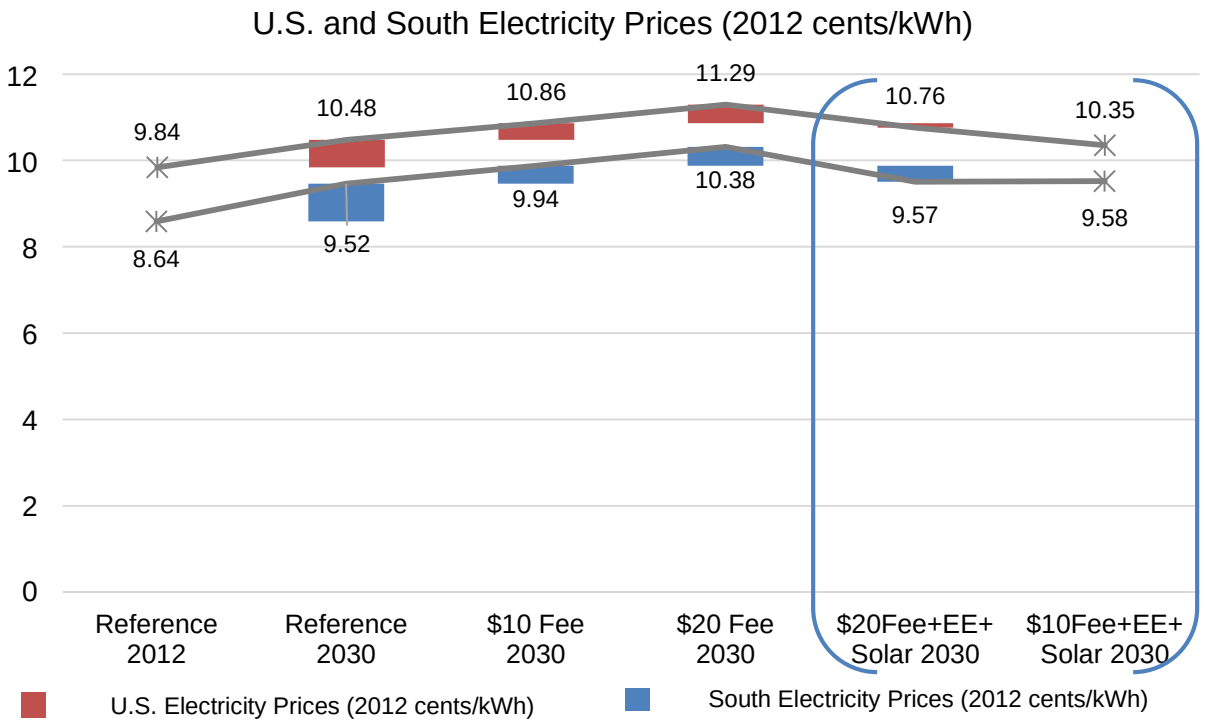
# Wholesale generation price, solar $/kW, and trading may explain solar tipping



| | | High CT $/kW | Low PV $/kW | High Demand Growth | High Natural Gas prices | High Wholesale Prices | High Power Imports |
|---|---|---|---|---|---|---|---|
| Solar Tipping Point | TRE | | X | X | | X | |
| | FRCC | X | X | | X | X | X |
| | SPPS | X | | | | | X |
| | SRVC | | X | X | X | X | X |
| No tipping point | SRDA | | | | | X | X |
| | SRCE | | | X | X | | |
| | SRSE | X | X | X | X | | |

# The Compliance Pathways Cut Electricity Bills Without Inflating Retail Rates

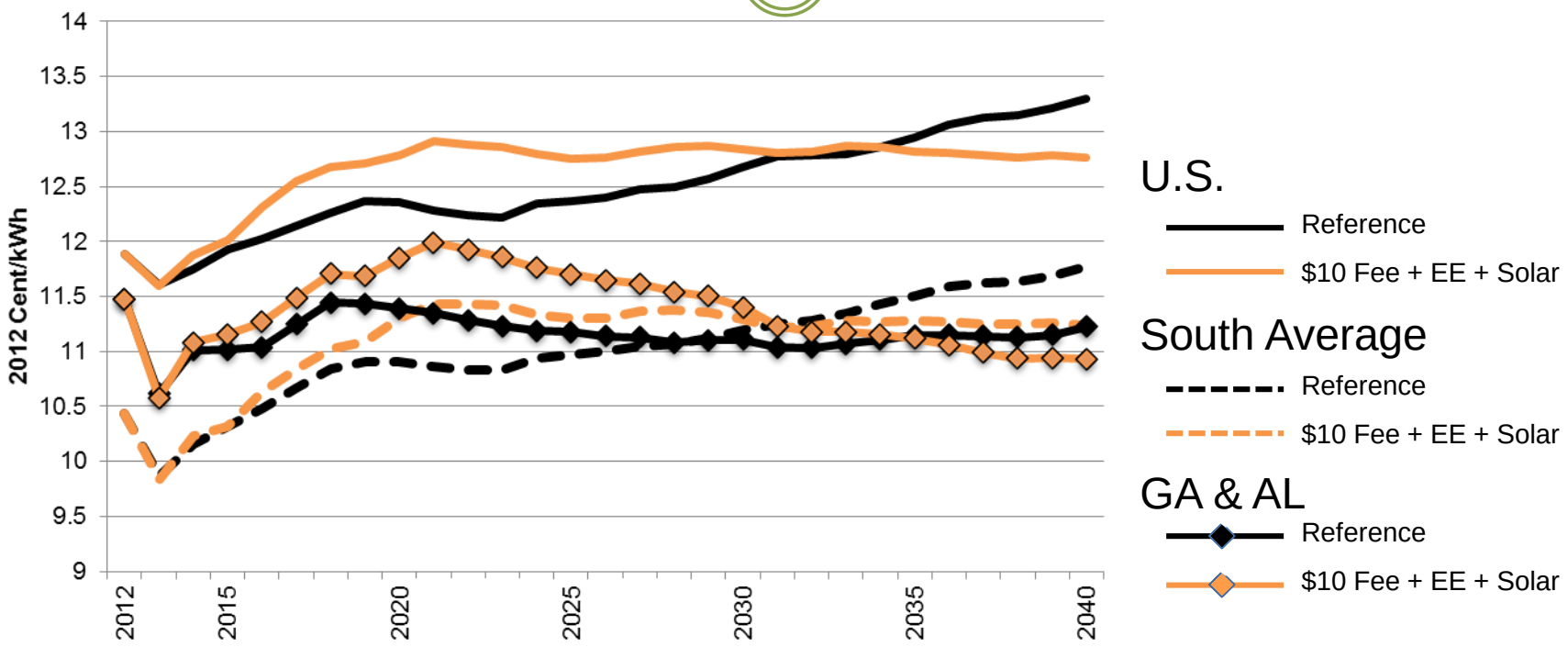





Residential bills in $10Fee+EE+Solar case in 2030 are 376 TWh (24%) lower than in the Reference case forecast for 2030, saving $46 billion (in $2012).

# Impacts on Residential Electricity Rates

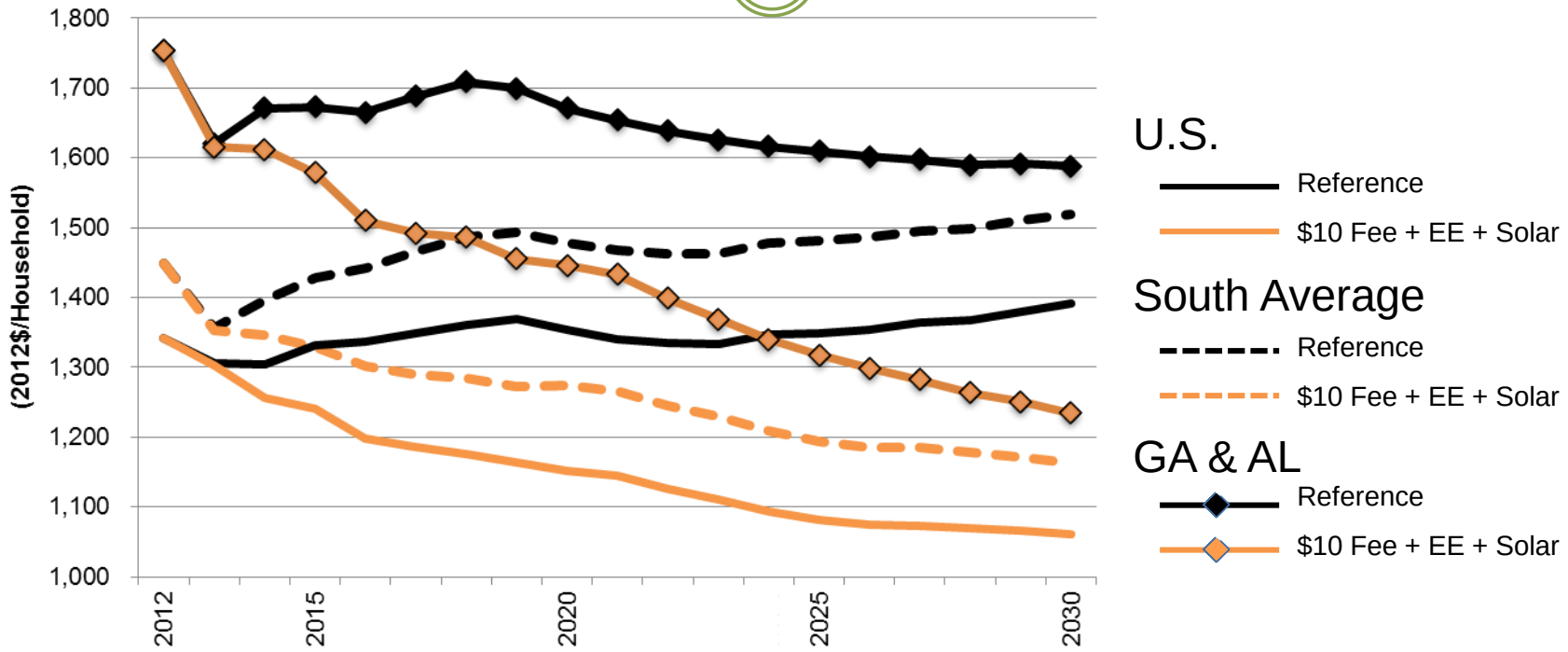





- EIA forecasts that electricity rates will rise in the U.S. and the South over the next 15 years, even without new regulations.
- State commitment to energy efficiency and solar can support continued operation of fossil plants, while avoiding additional capital expenditures on new power generation and transmission, leading to lower rates over the long term.

# Impact on Household Electricity Bills

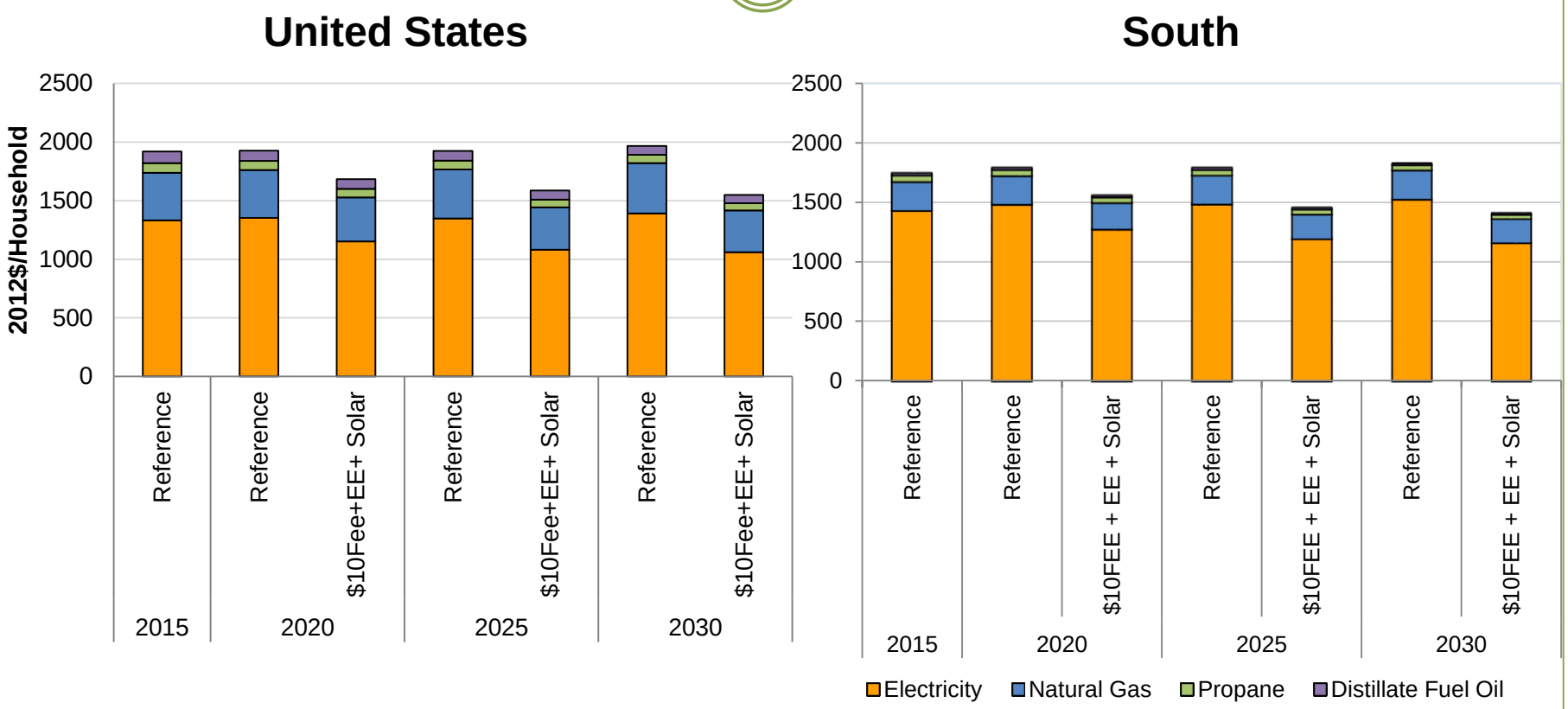





- EIA forecasts that household bills will rise in the U.S. and the South over the next 15 years, even without new regulations.
- Smart state policies can reduce carbon emissions and also cut household electricity bills in Georgia and Alabama.

# Impact on Energy Bills per Household

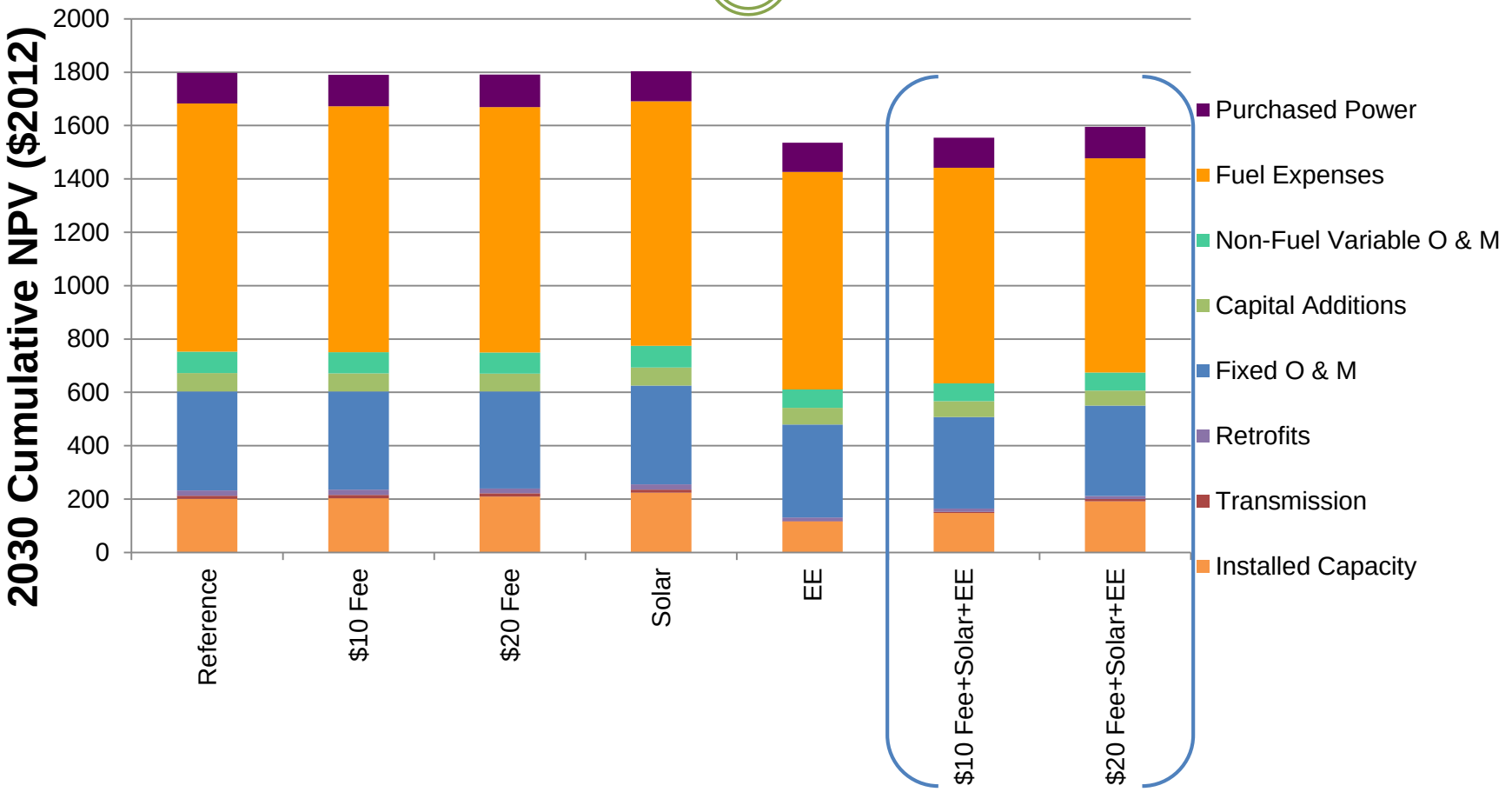





- Prices per cubic foot of natural gas rise because of upward market pressure from its expansion as a fuel for electric generation;
- However, natural gas bills would decline due to more efficient gas furnaces and water heaters.

# Electricity Total Resource Costs Are Less Under Compliance Pathways

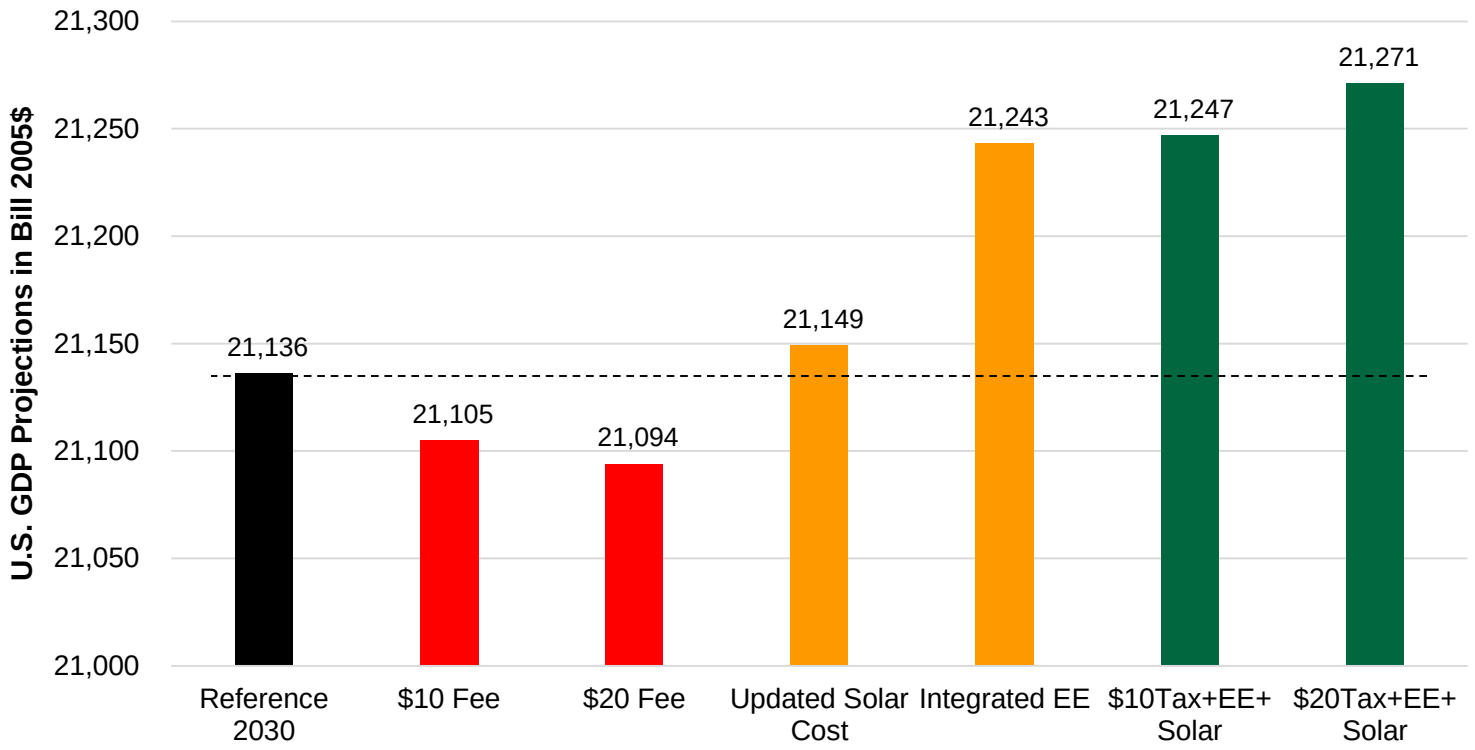





- Cost savings are likely due to EE reducing electricity sales
- $20Fee+EE+Solar exhibits more utility investment in solar power

# GDP Grows Slightly More in the Compliance Pathways



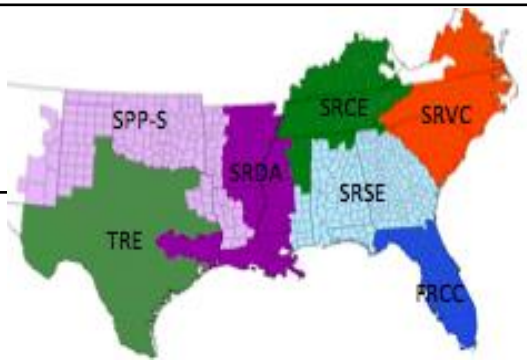



*Reference 2012: $13,593 billion

The value of industrial shipments and exports also increase in the compliance pathways

# Rate-Based Goals are Less Costly than Mass-Based Goals, Particularly in the South



| Performance with respect to CPP goals for 2030 | | $CO_2$ Fee+EE+Solar Required to Meet the Proposed Mass-Based Goals (Existing & New Units) | | |
|---|---|---|---|---|
| | | ≤$10/metric ton | $10 - $20/metric ton | >$20/metric ton |
| $CO_2$ Fee+EE+Solar Required to Meet the Proposed Rate-Based CPP Goals (Existing Units Only) | ≤$10/metric ton | | United States | South, SRCE, SRVC, SRSE |
| | $10 - $20/metric ton | SPSS | FRCC | SRDA |
| | >$20/metric ton |  | | TRE |

# Conclusions

# Conclusions



- CPP compliance can be achieved cost effectively with a combination of renewable and EE policies plus a modest price on carbon that could be expected to result from the Plan's implementation
- This compliance pathway would produce substantial collateral benefits including lower electricity bills across all customer classes, greater GDP growth, and significant reductions in $SO_2$, NOx, and mercury emissions
- Rate-based goals appear to be less costly than mass-based goals, particularly in the South

# For More Information



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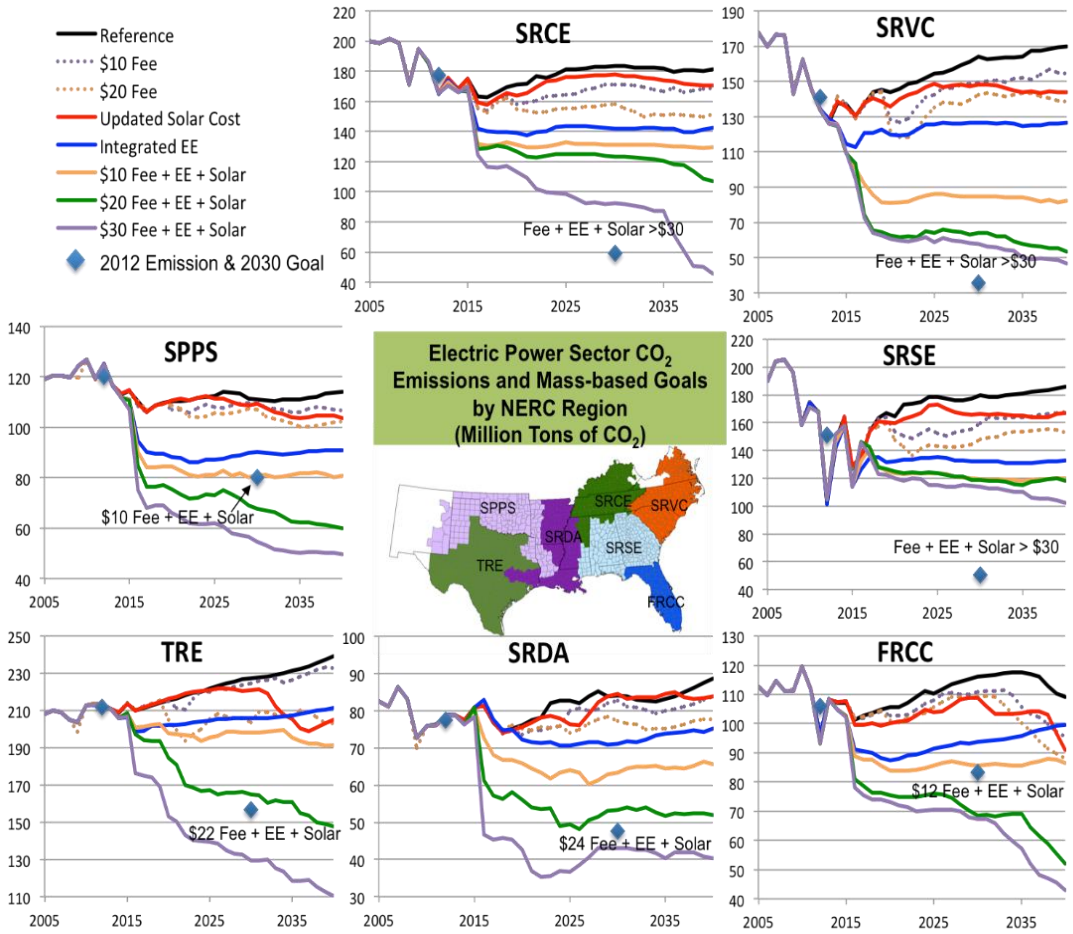
# Additional Documentation

# South Regional Mass-based Outcomes

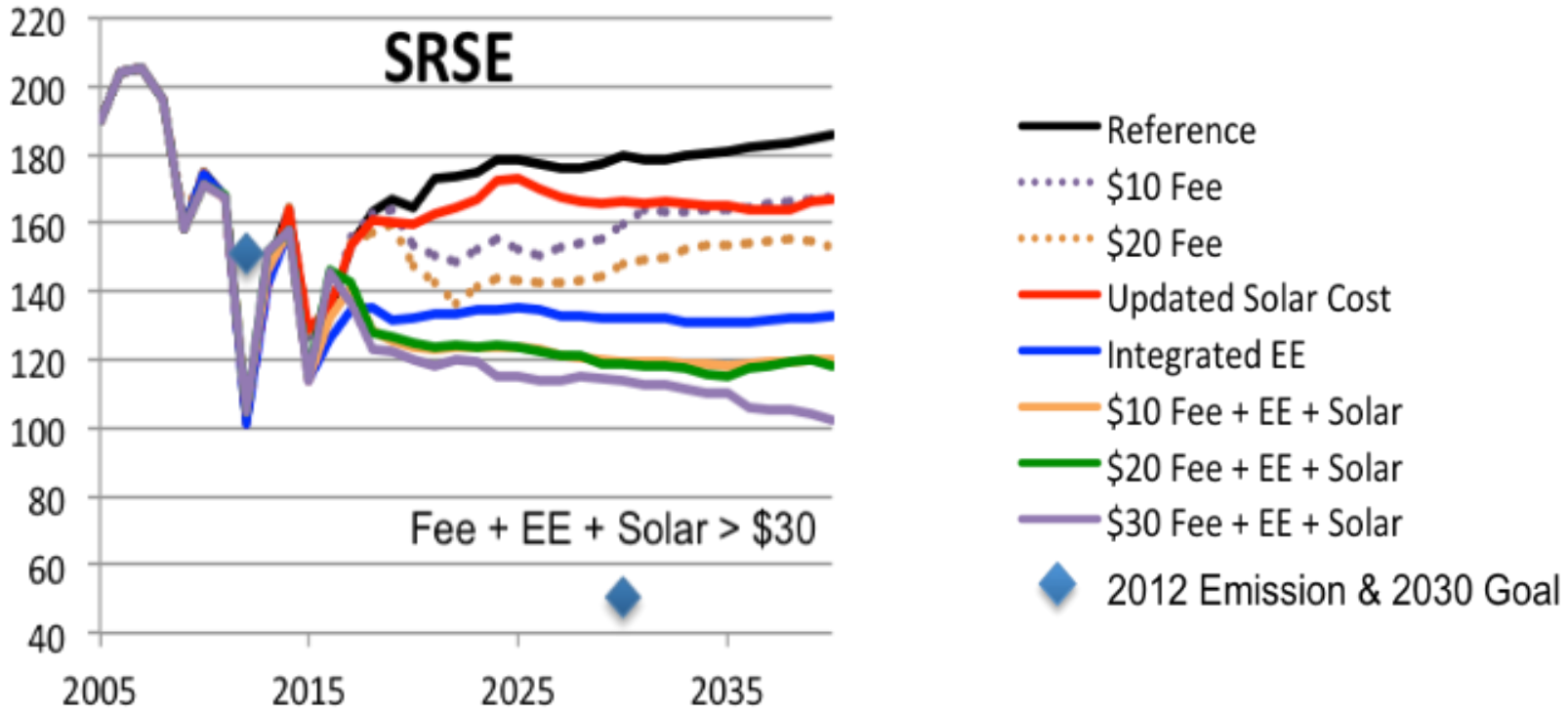





- Within the South:
  - 2 regions meet goal at between **$10**/ton-$CO_2$ and **$20**/ton-$CO_2$
  - 2 regions meet goal at between **$20**/ton-$CO_2$ and **$30**/ton-$CO_2$
  - 3 regions meet goal only at **>$30**/ton-$CO_2$

# SRSE Mass-based Outcomes



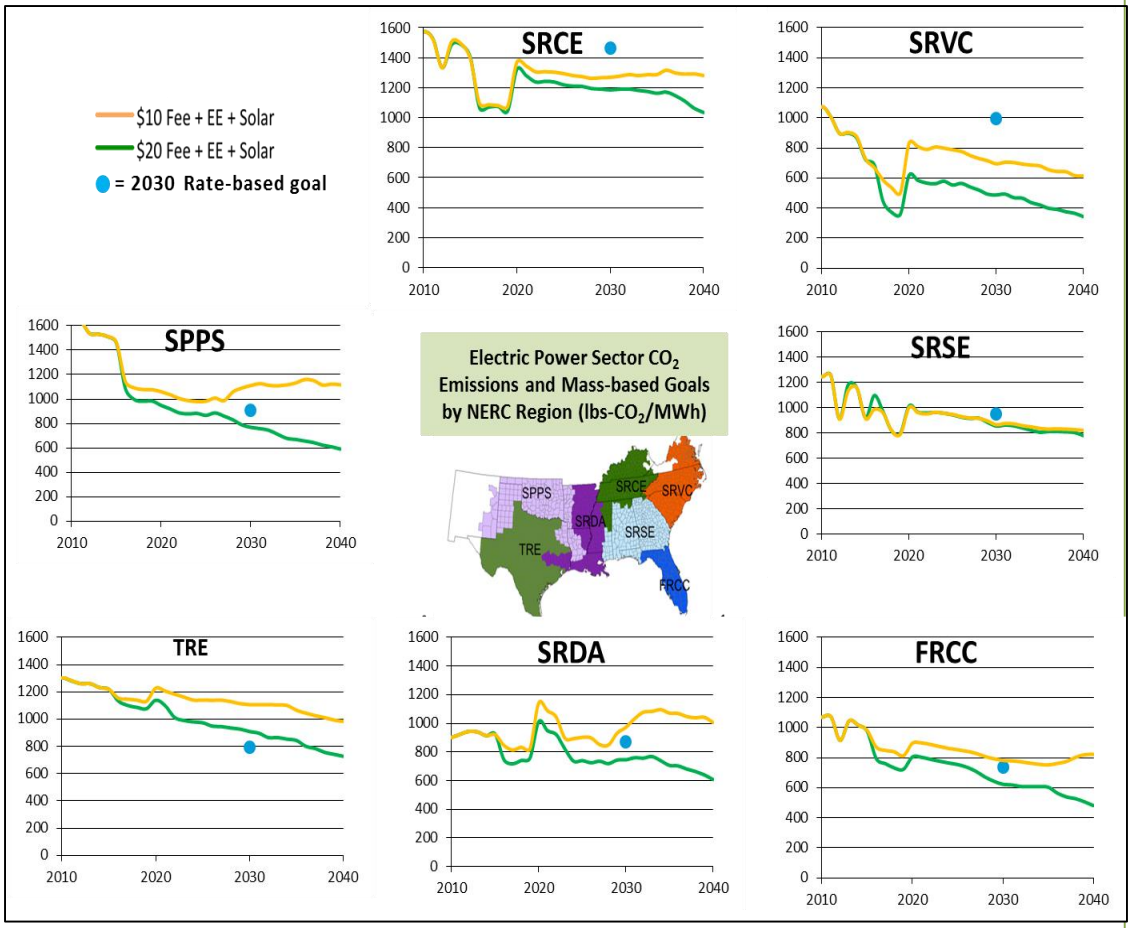


# South Regional Rate-based Outcomes



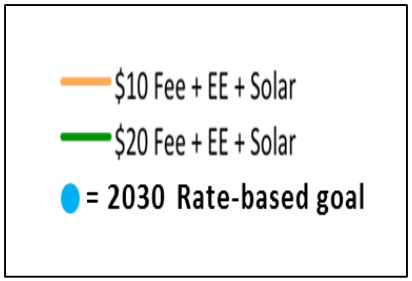
Within the South:

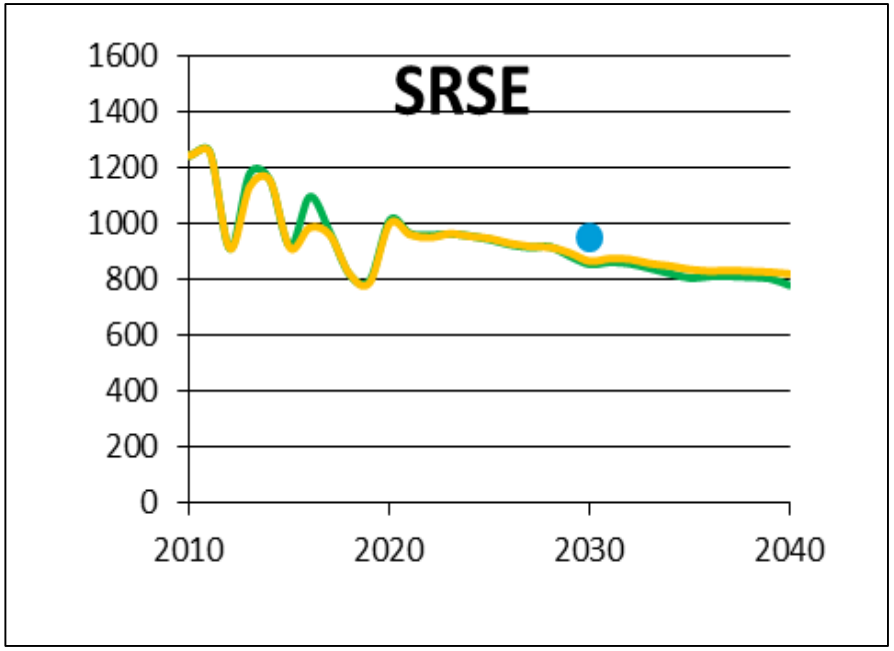
- 3 regions meet goal at <**$10**/ton-$CO_2$
- 3 regions meet goal at between **$10**/ton-$CO_2$ and **$20**/ton-$CO_2$
- 1 region meets goal only at **>$20**/ton-$CO_2$



# SRSE Rate-based Outcomes



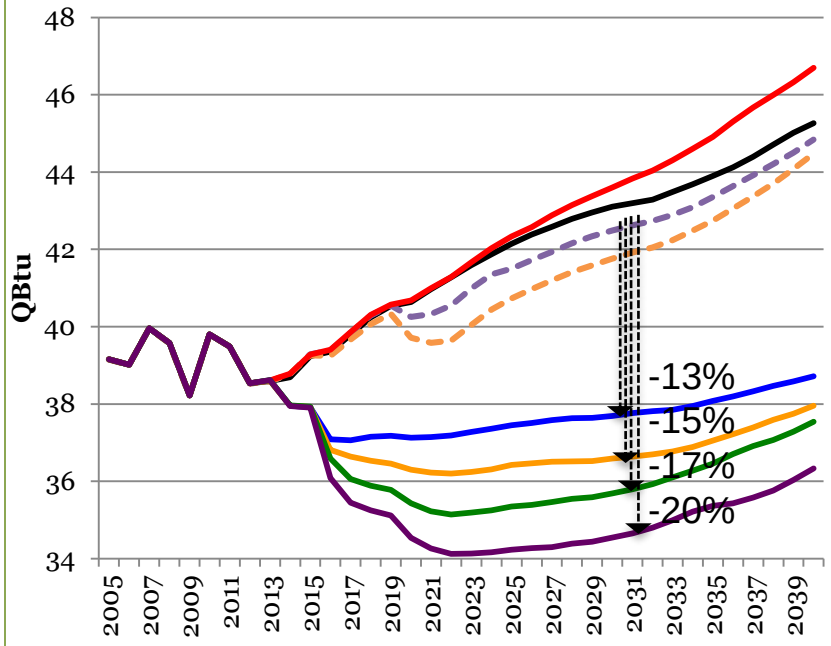


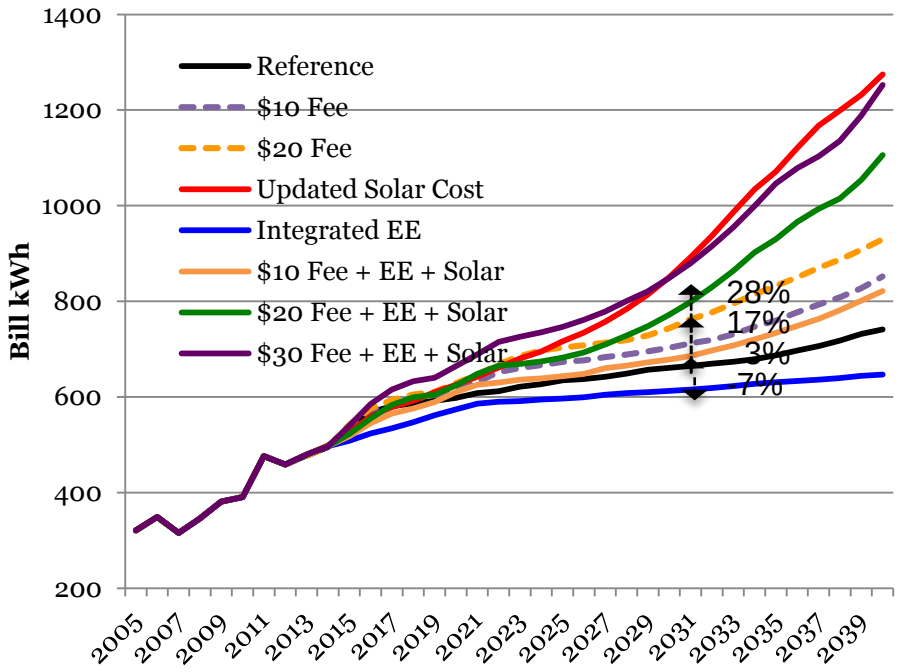
# Compliance Scenarios Drive End-Use Efficiency and Renewables



## Total Energy Use in Electric Power Sector




## Renewable Energy Generation in Electric Power Sector



# Renewable Energy Generation in 2030



| Abbreviation* | RE Generation in 2030 Ref (Billion KWh) | RE Generation in 2030 $10Fee++ (Billion KWh) |
|---|---|---|
| **1. TRE** | 33 | 37 |
| **2. FRCC** | 4 | 10 |
| 12. SRDA | | |
| 14. SRSE | | |
| 15. SRCE | | |
| **16. SRVC** | 16 | 43 |
| **18. SPPS** | 18 | 26 |

*Regions that tip to solar between $10 and $20 Fee in combination with EE and updated solar.

# Residential Electricity Prices and Bills



| | | Electricity rates (2012 cents/kWh) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Scenario** | 2012 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 |
| U.S. | Reference Case | 11.88 | 11.93 | 12.36 | 12.37 | 12.67 | 12.94 | 13.29 |
| | $10Fee+EE+Solar | 11.88 | 12.02 | 12.78 | 12.75 | 12.83 | 12.82 | 12.76 |
| | Difference | 0.00 | 0.09 | 0.42 | 0.38 | 0.16 | -0.12 | -0.53 |
| South | Reference Case | 10.73 | 10.44 | 11.01 | 11.03 | 11.27 | 11.55 | 11.81 |
| | $10Fee+EE+Solar | 10.73 | 10.42 | 11.34 | 11.32 | 11.34 | 11.34 | 11.31 |
| | Difference | 0.00 | -0.02 | 0.33 | 0.29 | 0.07 | -0.21 | -0.50 |

| | | Annual Electricity Bills per Household (2012 Dollars per Household of 2.58 Persons) | | | | |
|---|---|---|---|---|---|---|
| | **Scenario** | 2012 | 2015 | 2020 | 2025 | 2030 |
| U.S. | Reference Case | 1341 | 1331 | 1353 | 1349 | 1391 |
| | $10Fee+EE+Solar | 1341 | 1241 | 1152 | 1082 | 1061 |
| | Difference | 0.0 | -90 | -201 | -267 | -330 |
| | % Change | 0% | -6.8% | -14.9% | -19.8% | -23.7% |
| South | Reference Case | 1450 | 1428 | 1478 | 1480 | 1520 |
| | $10Fee+EE+Solar | 1450 | 1329 | 1275 | 1194 | 1163 |
| | Difference | 0.0 | -99 | -203 | -286 | -357 |
| | % Change | 0% | -7.0% | -13.8% | -19.4% | -23.5% |